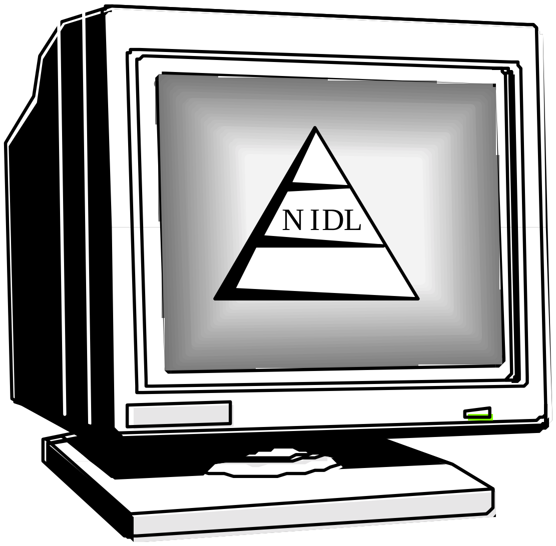

The Sun 365-1352-01 24 inch monitor (24-inch CRT size, 22.5" viewable area; the Sun selling price is $2500) made by Sony is a color monitor with excellent image quality and features that make it an excellent display device for NIMA Imagery Exploitation Capability workstations. NIDL certifies the Sun 365-1352-01 and the Sony GDM-W900 look-alike color monitors as being suitable for IEC workstations. NIDL rates this color monitor as an "A" for the Image Analyst and Cartographer applications.

Evaluation of the Sun Microsystems 365-1352-01 16 x 10 Aspect Ratio, 24-Inch Diagonal Color Monitor

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Abstract

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CONTENTS

NIDL IEC Monitor Certification Report

The Sun Microsystems 365-1352-01 Color CRT Monitor

FINAL GRADE: A

A=Substantially exceeds IEC Requirements; B= Meets IEC Requirements; C=Nearly meets IEC Requirements; F=Fails to meet IEC Requirements in a substantial way

The Sun 365-1352-01 24 inch monitor (24-inch CRT size, 22.5" viewable area; the Sun selling price is $2500) made by Sony is a color monitor with excellent image quality and features that make it an excellent display device for NIMA Imagery Exploitation Capability workstations. NIDL certifies the Sun 365-1352-01 and the Sony GDM-W900 look-alike color monitors as being suitable for IEC workstations. NIDL rates this color monitor as an “A” for the Image Analyst and Cartographer applications.

Easy to set up and run with a minimum of down time, the Sun 365-1352-01 is a versatile color monitor for demanding display applications. This monitor is an OEM product of the well-regarded Sun GDM-W900 series that has been on the market for several years. The reliability of the Sun Microsystems 365-1352-01 monitor is very good. NIDL has used the Sony GDM-W900 version of this monitor for several years now without any failures and with continued excellent performance.

The 16:10 wide aspect ratio and the 24 inch diagonal give the analyst a larger working area than a 21 inch monitor. The monitor performs best in the monoscopic mode and will display up to 1920 x 1200 pixels. In the stereo mode, the refresh rate of 46 Hz per eye and the 12.9:1 extinction ratio are less than required in the IEC specification so stereo performance may be less than experienced with a monochrome display.

The monitor can be used with the factory preset adjustments in Standard Mode. For greater versatility, the Expert Mode functions allow the user 30 image controls to enhance picture sharpness and increase luminance. One feature is a Moiré control circuit that can be turned on; it effectively reduces the appearance of a blurred image. Moiré (as when two window screens are rotated and viewed through one another) can arise under certain conditions from the interaction of the shadow mask in the CRT with the image displayed on the screen. Input to the Sun monitor is via a 2-meter non-detachable 13W3 video input cable and HD15-pin video input connector.

The Sun/Sony monitor passes nearly all the IEC specifications listed in the following Table. The manufacturer lists the native addressability as 1920 x 1200 pixels. However, the phosphor pitch of 0.25 to 0.28 mm limits the number of red, green and blue triads that can be addressed to less than 1920 pixels in the horizontal direction. NIDL’s measurements indicate a maximum of 1664 to 1856 pixels based on the pixel pitch.

The Sony GDM-W900 version of this monitor is described on the website, http://www.ita.sel.sony.com/products/displays/wide/gdmw900.html .

The Sun description is given on their website: http://store.sun.com/catalog/doc/BrowsePage.jhtml;$sessionid$ZEXHONAAABRVRAMUVIKSPJT5AAAACJ1K?cid=28772 . Part Number: X7124A ; List Price: 2,500.00 USD; Package Description: 24-inch wide-screen color monitor, 96 KHz, DDC1/2B, MPR-II, TXO 92, 1920 x 1200 at 70Hz with U.S. power cord and documentation. Does not include graphics board.

Evaluation Datasheet

Mode	IEC Requirement	Measured Performance			Compliance
MONOSCOPIC					
Addressability	1024 x 1024 min.	1280 x 1024	1620 x 1024	1920 x 1200	Pass
Dynamic Range	24.7dB	26.3dB	25.8dB	24.9dB	Pass
Luminance (Lmin)	0.1 fL min. ± 4%	0.11 fL	0.1	0.1	
Luminance (Lmax)	30 fL ± 4%	46.7 fL	38.1	31.0	Pass
Uniformity (Lmax)	20% max.	13.30%	15.70%	9.40%	Pass
Halation	3.5% max.	3.75% ± 0.3%	Not measured	Not measured	Pass
Color Temp	6500 to 9300 K	8613 K	8702 K	9132 K	Pass
Reflectance	Not specified	6.20%	Not measured	Not measured	
Bit Depth	8-bit± 5 counts	8-bit	Not measured	Not measured	Pass
Step Response	No visible ringing	Clean	Clean	Clean	Pass
Uniformity (Chromaticity)	0.010 delta u'v' max. ± 0.005 Δ u’v’	0.007 delta u'v'	0.009 delta u'v'	0.0063 delta u'v'	Pass
Pixel aspect ratio	Square H = V± 6%	11.78 x 11.70 mils, H x V	11.65 x 11.65 mils, H x V	9.87 x 9.93 mils, HxV	Pass
Screen size, viewable diagonal	17.5 to 24 inches ± 2 mm	19.256 ins. 15.078 H x 11.978 V	22.329 ins. 18.874H x 11.933 V	22.381 ins. 18.944 H x 11.917 V	Pass
Cm, Zone A	25% min.	60%	64%	51%*	Pass *
Cm, Zone B	20% min.	36%	53%	35%*	Pass *
Pixel density	72 ppi min.	85 ppi	86 ppi	101 ppi	Pass
Moire, phosphor-to-pixel spacing	1.0 max	0.94 0.28mm/ 11.78 mils	0.95 0.28mm/ 11.65 mils	1.12* 0.28mm / 9.87 mils	Pass *
Straightness	0.5% max ± 0.05 mm	0.29%	0.36%	0.30%	Pass
Linearity	1.0% max ± 0.05 mm	0.76%	0.87%	0.59%	Pass
Jitter	2 ± 2 mils max.	2.3 mils	Not measured	2.59 mils	Pass
Swim, Drift	5 ± 2 mils max.	2.8 mils	Not measured	3.15 mils	Pass
Warmup time, Lmin to +/- 50%	30 mins. Max ± 0.5 minute	< 1 min.	Not measured	Not measured	Pass
Warmup time, Lmin to +/- 10%	60 mins. Max ± 0.5 minute	23 mins.	Not measured	Not measured	Pass
Refresh	72 ±1 Hz min. 60 ±1 Hz absolute minimum	Set to 72 Hz	Set to 72 Hz	Set to 60 Hz Max. 76 Hz	Pass
STEREOSCOPIC					
Addressability	1024 x 1024 min.	1024 x 2048 (I)			Pass
Lmin	0.1 fl	0.10 fL			
Lmax	6 fL min ± 4%	6.39 fL			Pass
Dynamic range	17.7 dB min	18.0 dB			Pass
Uniformity (Chromaticity)	0.02 delta u'v' max ± 0.005 Δ u’v’	0.007 delta u'v'			Pass
Refresh rate	60 Hz per eye, min	46 Hz, per eye			Fail
Extinction Ratio	15:1 min	12.9:1			Fail

* denotes Moire cancellation turned ON
(I) denotes interlaced scanning
(n) denotes Nuvision LCD shutter panel

Section I INTRODUCTION

The National Information Display Laboratory (NIDL) was established in 1990 to bring together technology providers - commercial and academic leaders in advanced display hardware, softcopy information processing tools, and information collaboration and communications techniques - with government users. The NIDL is hosted by the Sarnoff Corporation in Princeton, New Jersey, a world research leader in high-definition digital TV, advanced displays, computing and electronics.

The present study evaluates a production unit of the Sun Microsystems 365-1352-01, color CRT high-resolution display monitor. This report is intended for both technical users, such as system integrators, monitor designers, and monitor evaluators, and non-technical users, such as image analysts, software developers, or other users unfamiliar with detailed monitor technology.

The IEC requirements, procedures and calibrations used in the measurements are detailed in the following:

- *NIDL Publication No. 0201099-091***,** *Request for Evaluation Monitors for the National Imagery & Mapping Agency (NIMA) Integrated Exploitation Capability (IEC),* August 25, 1999.

Two companion documents that describe how the measurements are made, are available from the NIDL and the Defense Technology Information Center at http://www.dtic.mil:

- *NIDL Publication No. 171795-036 Display Monitor Measurement Methods under Discussion by EIA (Electronic Industries Association) Committee JT-20 Part 1: Monochrome CRT Monitor Performance Draft Version 2.0. (ADA353605)*

- *NIDL Publication No. 171795-037 Display Monitor Measurement Methods under Discussion by EIA (Electronic Industries Association) Committee JT-20 Part 2: Color CRT Monitor Performance Draft Version 2.0. (ADA341357)*

Other procedures are found in a recently approved standard available from the Video Electronics Standards Association (VESA) at http://www.vesa.org:

- *VESA Flat Panel Display Measurements Standard, Version 1.0, May 15, 1998.*
  Publication No. 0201099-091, Request for Evaluation Monitors for the National Imagery & Mapping Agency (NIMA) Integrated Exploitation Capability (IEC), August 25, 1999.

The IEC workstation provides the capability to display image and other geospatial data on either monochrome or color monitors, or a combination of both. Either of these monitors may be required to support stereoscopic viewing. Selection and configuration of these monitors will be made in accordance with mission needs for each site. NIMA users will select from monitors included on the NIMA-approved Certified Monitor List compiled by the NIDL. The color and monochrome, monoscopic and stereoscopic, monitor requirements are listed in the Evaluation Datasheet.

I.1 The Sun Microsystems 365-1352-01 Color CRT Monitor

Manufacturer's Specifications

According to Sony, the specifications for the Sony GDM-W900 look-alike to the Sun monitor are:

- **Resolution**: up to 1920 x 1200 @ 76Hz; Mode 1: 640 x 480 @ 60Hz Mode 2: 1280 x 1024 @ 75Hz Mode 3: 1600 x 1200 @ 75Hz Mode 4: 1920 x 1080 @ 60Hz Mode 5: 1920 x 1080 @ 50Hz Mode 6: 1600 x 1024 @ 76Hz Mode 7: 1920 x 1200 @ 76Hz Mode 8: 720 x 400 @ 70 Hz

- **CRT**: Trinitron Technology with magnetic deflection, electrostatic focus precision in-line gun (with In-Line cathode, Bi-Uni-potential Focus System with Quadrapole Lens) and aperture grille technology, cylindrical face plate, Conductive AR Film Coating, 48% transmission glass, P22 phosphor, phosphor or trio pitch is 0.26 mm center to 0.29 mm corner, 90 degree deflection angle, Tension band implosion protection system. The multi-layer AR film coating reduces ambient light reflection while the ITO coating helps reduce emission of low frequency electric fields (VLF/ELF countermeasure). The bonding resin is a conductive material to minimize the static charge built up on the face plate
- **Power Requirement**: 100-120 VAC 50/60 Hz; 200-240 VAC 50/60 Hz; <200W during operation
- **Signal Interface**: 5 BNCs and one D-sub 15HD for R, G, B, H-sync and V-sync. Each R, G, B video input is terminated with 75 ohm and allows +/- 5% variation from a nominal amplitude of +0.714 Vp-p
- **Scan timing**: Horizontal 30kHz to 96 kHz; Vertical 50-160 Hz;
- **Video amplifier**: Bandwidth 50 Hz to 170 MHz; Pulse Rise/Fall Time <4.0 ns
- **Geometric Distortion**: For primary mode signal, the perimeter falls within the following ranges +/- 1.5/1.9 mm around edges of the picture; for other signals, +/- 2.2 mm around edges of the picture.
- **Deflection linearity**: Absolute positional error on X and Y axis within the display image is less than +/- 1% of the vertical height.
- **Color Purity**: Measured with a flat field white signal of 100% average picture level (APL), contrast control set to maximum and brightness to center, using a Minolta TV color Analyzer II or Minolta CA-100, calibrated by Sony, and a warm-up of no less than 30 minutes, the measurement at screen center and at 25 mm inside of each corner should give: Red raster x=0.625 +/-0.020 and y=0.340+/-0.020; green raster x=0.280+/-0.020 and y=0.595+/-0.020; Blue raster=0.155+/-0.015 and y=0.070+/-0.015.
- **Physical Dimensions**: Length: 22.8 inches, Width/Depth: 21.6 inch, Height: 19.8 inch, Weight: 90.4 pounds

I.2. Initial Monitor Set Up

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5, p 5.

All measurements will be made with the display commanded through a laboratory grade programmable test pattern generator. The system will be operated in at least a 24 bit mode (as opposed to a lesser or pseudo-color mode) for color and at least 8 bits for monochrome. As a first step, refresh rate should be measured and verified to be at least 72 Hz. The screen should then be commanded to full addressability and Lmin set to 0.1 fL. Lmax should be measured at screen center with color temperature between D65 and D93 allowable and any operator adjustment of gain allowable. If a value >35fL is not achieved (>30 fL for color), addressability should be lowered. For a nominal 1200 by 1600 addressability, addressability should be lowered to 1280 by 1024 or to 1024 by 1024. For a nominal 2048 by 2560 addressability, addressabilities of 1200 x 1600 and 1024 x 1024 can be evaluated if the desired Lmax is not achieved at full addressability.

I.3. Equipment

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 2.0, page 3.

The procedures described in this report should be carried out in a darkened environment such that the stray luminance diffusely reflected by the screen in the absence of electron-beam excitation is less than 0.003 cd/m^2 (1mfL).

Instruments used in these measurements included:

- Quantum Data 8701 400 MHz programmable test pattern signal generator
- Quantum Data 903 250 MHz programmable test pattern signal generator
- Photo Research SpectraScan PR-650 spectroradiometer
- Photo Research SpectraScan PR-704 spectroradiometer
- Minolta LS-100 Photometer
- Minolta CA-100 Colorimetermeter
- Graseby S370 Illuminance Meter
- Microvision Superspot 100 Display Characterization System which included OM-1 optic module (Two Dimensional photodiode linear array device, projected element size at screen set to 1.3 mils with photopic filter) and.Spotseeker 4-Axis Positioner

Stereoscopic-mode measurements were made using the following commercially-available stereo products:

- Nuvision 19-inch LCD shutter with passive polarized eyeglasses.

Section II PHOTOMETRIC MEASUREMENTS

II.1. Dynamic range and Screen Reflectance

References: *Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.6, p 6.*

VESA Flat Panel Display Measurements Standard, Version 1.0, May 15, 199, Section 308-1.

Full screen white-to-black dynamic range measured in 1280 x 1024 format decreases from 26.3 dB in a dark room to 22 dB (the absolute threshold for IEC) in 3 fc diffuse ambient illumination.

Objective: Measure the photometric output (luminance vs. input command level) at Lmax and Lmin in both dark room and illuminated ambient conditions.

Equipment: Photometer, Integrating Hemisphere Light Source or equivalent

Procedure: Luminance at center of screen is measured for input counts of 0 and Max Count. Test targets are full screen (flat fields) where full screen is defined addressability. Set Lmin to 0.1 fL. For color monitors, set color temperature between D_{65} to D_{93} . Measure Lmax.

This procedure applies when intended ambient light level measured at the display is 2fc or less. For conditions of higher ambient light level, Lmin and Lmax should be measured at some nominal intended ambient light level (e.g., 18-20 fc for normal office lighting with no shielding). This requires use of a remote spot photometer following procedures outlined in reference 2, paragraph 308-2. This will at best be only an approximation since specular reflections will not be captured. A Lmin > 0.1 fL may be required to meet grayscale visibility requirements.

According to the VESA directed hemispherical reflectance (DHR) measurement method, total combined reflections due to specular, haze and diffuse components of reflection arising from uniform diffuse illumination are silmutaneously quantified as a fraction of the reflectance of a perfect white diffuse reflector using the set up depicted in figure II.1-1. Total reflectance was calculated from measured luminances reflected by the screen (display turned off) when uniformly illuminated by an integrating hemisphere simulated using a polystyrene ice box. Luminance is measured using a spot photometer with 1° measurement field and an illuminance sensor as depicted in Figure II.1-1. The measured values and calculated reflectances are given in Table II.1-1.

Data: Define dynamic range by: DR=10log(Lmax/Lmin)

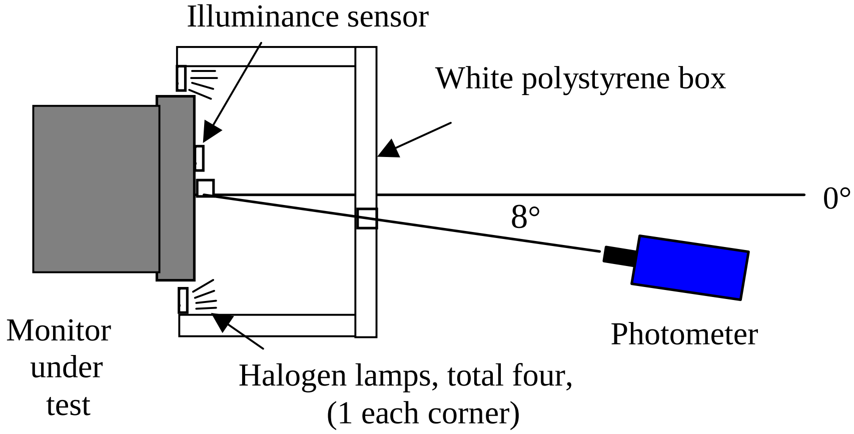


Figure II.1-1. Test setup according to VESA FPDM procedures for measuring total reflectance of screen.

Table II.1-1. Directed Hemispherical Reflectance of Faceplate

VESA ambient contrast illuminance source (polystyrene box)

Ambient Illuminance	25.5 fc
Reflected Luminance	1.59 fL
Faceplate Reflectance	6.2%

Ambient dynamic ranges of full screen white-to-black given in Table II.1-2 were computed for various levels of diffuse ambient lighting using the measured value for DHR and the darkroom dynamic range measurements. Full screen white-to-black dynamic range decreases from 26.3 dB in a dark room to 22 dB (the absolute threshold for IEC) in 3 fc diffuse ambient illumination.

Table II.1-2.Dynamic Range in Dark and Illuminated Rooms

Effect of ambient lighting on dynamic range is calculated by multiplying the measured CRT faceplate reflectivity times the ambient illumination measured at the CRT in foot candles added to the minimum screen luminance, Lmin, where Lmin = 0.1 fL.

	Displayed Addressable Format		
Ambient Illumination	**1280 x 1024**	**1620 x 1024**	**1920 x 1200**
0 fc (Dark Room)	26.3 dB	25.8 dB	24.9 dB
1 fc	24.3 dB	23.7 dB	22.8 dB
2 fc	23.0 dB	22.3 dB	21.4 dB
3 fc	22.0 dB	21.3 dB	20.4 dB
4 fc	21.2 dB	20.4 dB	19.5 dB
5 fc	20.5 dB	19.7 dB	18.8 dB
6 fc	19.9 dB	19.1 dB	18.2 dB
7 fc	19.4 dB	18.6 dB	17.7 dB
8 fc	18.9 dB	18.1 dB	17.2 dB
9 fc	18.5 dB	17.7 dB	16.8 dB
10 fc	18.1 dB	17.3 dB	16.4 dB

II.2. Maximum Luminance (Lmax)

References: *Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.2, p 6.*

The highest luminance for Lmax was 46.7 fL measured at screen center in 1280 x 1024 format. Lmax dropped to 38.1 fL in 1620 x 1024 format, and dropped further to 31.0 fL in 1920 x 1200 format.

Objective: Measure the maximum output display luminance.

Equipment: Photometer

Procedure: See dynamic range. Use the value of Lmax defined for the Dynamic Range measurement.

Data: The maximum output display luminance, Lmax, and associated CIE x, y chromaticity coordinates (CIE 1976) were measured using a hand-held colorimeter (Minolta CA-100). The correlated color temperature (CCT) computed from the measured CIE x, y chromaticity coordinates was within range specified by IEC (6500K and 9300K).

Table II.2-1. Maximum Luminance and Color

Color and luminance (in fL) for Full screen at 100% Lmax taken at screen center.

Format	CCT	CIE x	CIE y	Luminance
1280 x 1024	8613 K	0.291	0.295	46.7 fL
1620 x 1024	8702 K	0.290	0.295	38.1 fL
1920 x 1200	9132 K	0.287	0.291	31.0 fL

II.3. Luminance (Lmax) and Color Uniformity

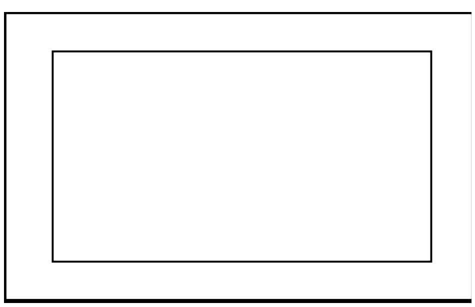
Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 4.4, p. 28.

Maximum luminance (Lmax) varied by up to 15.7% across the screen. Chromaticity variations were less than 0.009 delta u'v' units.

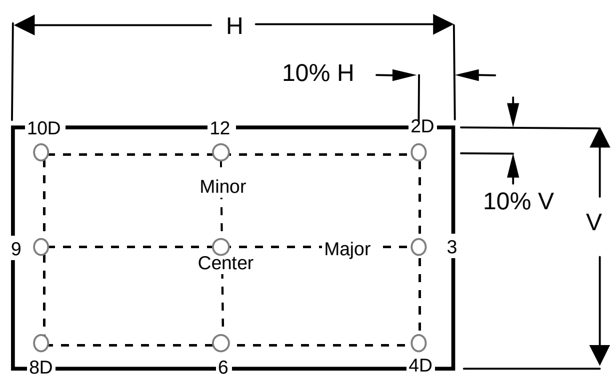
Objective: Measure the variability of luminance and chromaticity coordinates of the white point at 100% Lmax only and as a function of spatial position. Variability of luminance impacts the total number of discriminable gray steps.

Equipment:
- Video generator
- Photometer
- Spectroradiometer or Colorimeter

Test Pattern: Full screen flat field with visible edges at L_{min} as shown in Figure II.3-1.



Full Screen Flat Field test pattern.
Figure II.3-1



Nine screen test locations.
Figure II.3-2

Procedure: Investigate the temporal variation of luminance and the white point as a function of intensity by displaying a full flat field shown in Figure II.3-1 for video input count levels corresponding L_{max}. Measure the luminance and C.I.E. color coordinates at center screen.

Investigate the temporal variation of luminance and the white point as a function of spatial position by repeating these measurements at each of the locations depicted in Figure II.3-2. Define color uniformity in terms of Δ u´v´.

Data: Tabulate the luminance and 1931 C.I.E. chromaticity coordinates (x, y) or correlated color temperature of the white point at each of the nine locations depicted in Figure II.3-2. Additionally, note the location of any additional points that are measured along with the corresponding luminance values.

Table II.3-1.Spatial Uniformity of Luminance and Color

Color and luminance (in fL) for Full screen at 100% Lmax taken at nine screen positions.

1280 x 1024

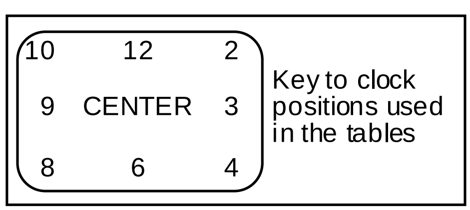
POSITION	CCT	CIE x	CIE y	L, fL
center	8613	0.291	0.295	46.7
2	8590	0.292	0.293	40.5
3	8492	0.292	0.296	42.1
4	8405	0.293	0.296	41.6
6	8524	0.292	0.295	41.1
8	8681	0.291	0.293	43.6
9	8809	0.290	0.292	45.2
10	8980	0.289	0.290	43.6
12	9398	0.287	0.285	41.2

1620 x 1024

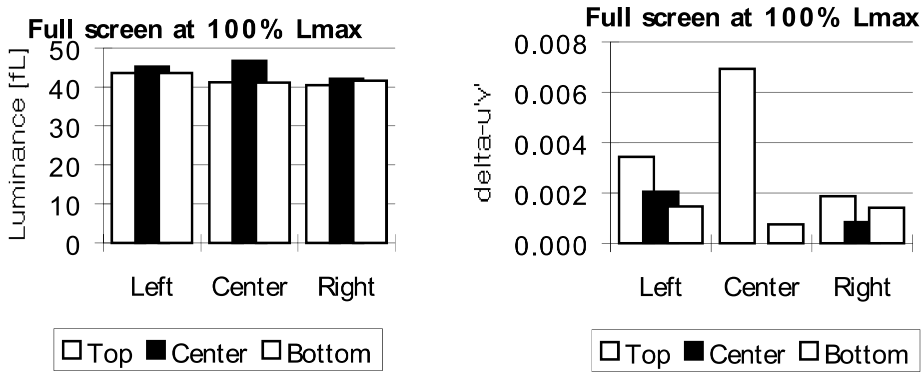
POSITION	CCT	CIE x	CIE y	L, fL
center	8702	0.290	0.295	38.1
2	8150	0.295	0.299	33.1
3	8430	0.292	0.298	35.6
4	9146	0.286	0.293	33.6
6	8996	0.288	0.292	36.1
8	10254	0.278	0.287	32.1
9	9283	0.285	0.292	35.3
10	8646	0.291	0.294	34.4
12	9454	0.286	0.286	34.2

1920 x 1200

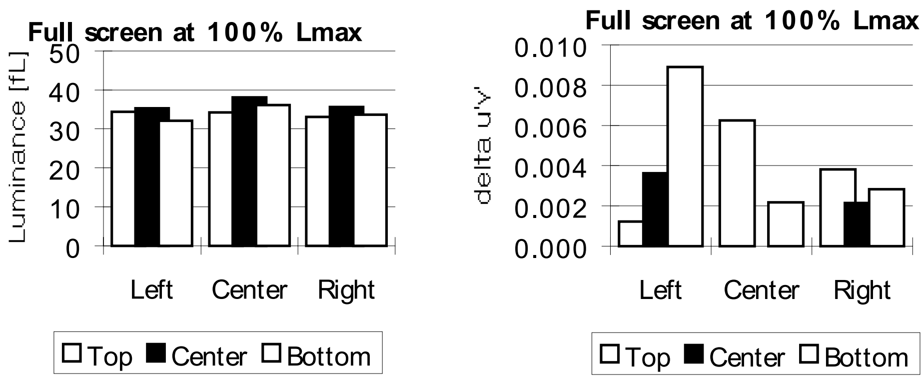
POSITION	CCT	CIE x	CIE y	L, fL
center	9132	0.287	0.291	31.0
2	8809	0.290	0.292	28.7
3	8613	0.291	0.295	29.5
4	9036	0.288	0.291	29.8
6	9260	0.287	0.288	28.7
8	8846	0.290	0.291	28.6
9	9217	0.287	0.289	30.2
10	8941	0.289	0.291	29.6
12	9988	0.283	0.282	28.1



1280 x 1024



1620 x 1024



1920 x 1200

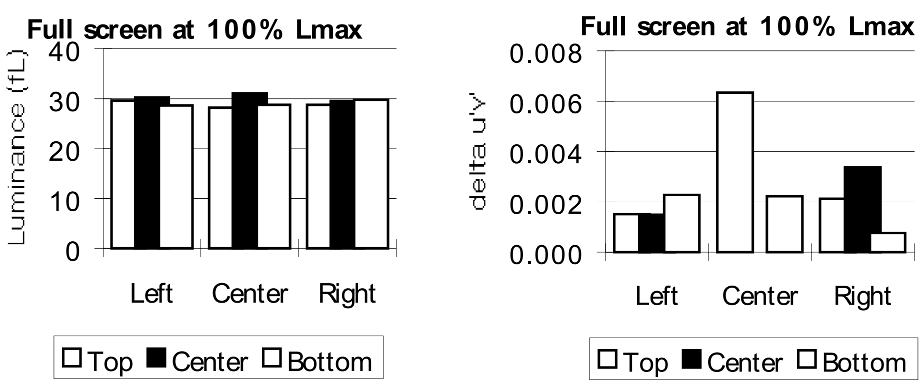


Fig.II.3-3. Spatial Uniformity of Luminance Chromaticity.
(Delta u'v' of 0.004 is just visible.)

II.4. Halation

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 4.6, page 48.

Halation was 3.75 % +/- 0.3% on a small black patch surrounded by a large full white area.

Objective: Measure the contribution of halation to contrast degradation. Halation is a phenomenon in which the luminance of a given region of the screen is increased by contributions from surrounding areas caused by light scattering within the phosphor layer and internal reflections inside the glass faceplate. The mechanisms that give rise to halation, and its detailed non-monotonic dependence on the distance along the screen between the source of illumination and the region being measured have been described by E. B. Gindele and S.L. Shaffer. The measurements specified below determine the percentage of light that is piped into the dark areas as a function of the extent of the surrounding light areas.

Equipment:
- Photometer
- Video generator

Test Pattern:

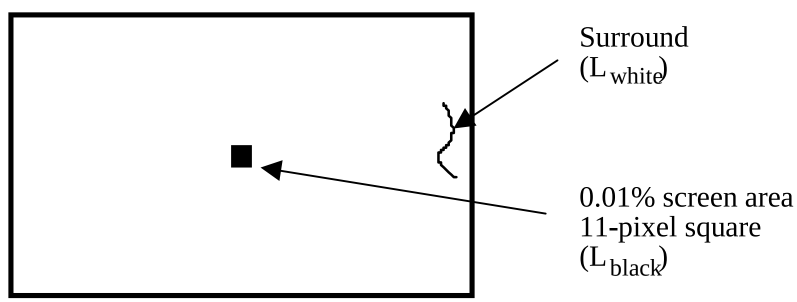


Figure II.4-1 *Test pattern for measuring halation.*

Procedure: Note: The halation measurements require changing the setting of the BRIGHTNESS control and will perturb the values of L_{max} and L_{min} that are established during the initial monitor set-up. The halation measurements should therefore be made either first, before the monitor setup, or last, after all other photometric measurements have been completed.

Determine halation by measuring the luminance of a small square displayed at L_{black} (essentially zero) and at L_{white} when surrounded by a much larger square displayed at L_{white} (approximately 75% L_{max}).

Establish L_{black} by setting the display to cutoff. To set the display to cut-off, display a flat field using video input count level zero, and use a photometer to monitor the luminance at center screen. Vary the BRIGHTNESS control until the CRT beam is visually cut off, and confirm that the corresponding luminance (L_{stray}) is essentially equal to zero. Fine tune the BRIGHTNESS control such that

CRT beam is just on the verge of being cut off. These measurements should be made with a photometer which is sensitive at low light levels (below L_{min} of the display). Make no further adjustments or changes to the BRIGHTNESS control or the photometer measurement field.

Next, decrease the video input level to display a measured full-screen luminance of 75% L_{max} measured at screen center. Record this luminance (L_{white}).

The test target used in the halation measurements is a black (L_{black}) square patch of width equal to 0.01% of the area of addressable screen, the interior square as shown in Figure II.4-1. The interior square patch is enclosed in a white (L_{white}) background encompassing the remaining area of the image. The exterior surround will be displayed at 75% L_{max} using the input count level for L_{white} as determined above. The interior square will be displayed at input digital count level zero.

Care must be taken during the luminance measurement to ensure that the photometer's measurement field is less than one-half the size of the interior square and is accurately positioned not to extend beyond the boundary of the interior square. The photometer should be checked for light scattering or lens flare effects which allow light from the surround to enter the photosensor. A black card with aperture equal to the measurement field (one-half the size of the interior black square) may be used to shield the photometer from the white exterior square while making measurements in the interior black square.

Analysis: Compute the percent halation for each test target configuration. Percent halation is defined as:

$$\% \text{ Halation} = L_{black} \ / \ (L_{white} - L_{black}) \times 100$$

Where, L_{black} = measured luminance of interior square displayed at L_{black} using input count level zero,

L_{white} = measured luminance of interior square displayed at L_{white} using input count level determined to produce a full screen luminance of 75% L_{max} .

Data: Table II.4-1 contains measured values of L_{black}, L_{white} and percentage halation.

Table II.4-1 Halation for 1280 x 1024 Addressability

	Reported Values	Range for 4% uncertainty
Lblack	1.24 fL ± 4%	1.19 fL to 1.29 fL
Lwhite	33.0 fL ± 4%	34.4 fL to 31.7 fL
Halation	**3.75% ± 0.3%**	**3.46% to 4.07%**

II.5. Color Temperature

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 5.4, page 22.

The CCT of the measured white point lies within the boundaries accepted by IEC.

Objective: Insure measured screen white of a color monitor has a correlated color temperature (CCT) between 6500K and 9300K.

Equipment: Colorimeter

Procedure: Command screen to Lmax. Measure u'v' chromaticity coordinates (CIE 1976).

Data: Coordinates of screen white should be within 0.01 Δu'v' of the corresponding CIE daylight, which is defined as follows: If the measured screen white has a CCT between 6500 and 9300 K, the corresponding daylight has the same CCT as the screen white. If the measured CCT is greater than 9300 K, the corresponding daylight is D93. If the measured CCT is less than 6500 K, the corresponding daylight is D65. The following equations were used to compute Δu'v' values listed in table II.5.1:

1. Compute the correlated color temperature (CCT) associated with (x,y) by the VESA/McCamy formula: CCT = 437 n^3 + 3601 n^2 + 6831 n + 5517, where n = (x-0.3320)/(0.1858 - y). [This is on p. 227 of the FPDM standard]

2. If CCT < 6500, replace CCT by 6500. If CCT > 9300, replace CCT by 9300.

4. Use formulas 5(3.3.4) and 6(3.3.4) in Wyszecki and Stiles (pp.145-146 second ed) to compute the point (xd,yd) associated with CCT.
   - First, define u = 1000/CCT.
   - If CCT < 7000, then xd = -4.6070 u^3 + 2.9678 u^2 + 0.09911 u +
   - 0.244063.
   - If CCT > 7000, then xd = -2.0064 u^3 + 1.9018 u^2 + 0.24748 u +
   - 0.237040.
   - In either case, yd = -3.000 xd^2 + 2.870 xd -0.275.

5. Convert (x,y) and (xd,yd) to u'v' coordinates:
   - (u',v') = (4x,9y)/(3 + 12y - 2x)
   - (u'd,v'd) = (4xd,9yd)/(3 + 12yd - 2xd)

6. Evaluate delta-u'v' between (u,v) and (ud,vd):
   - delta-u'v' = sqrt[(u' - u'd)^2 + (v' - v'd)^2].

7. If delta-u'v' is greater than 0.01, display fails the test. Otherwise it passes the test.

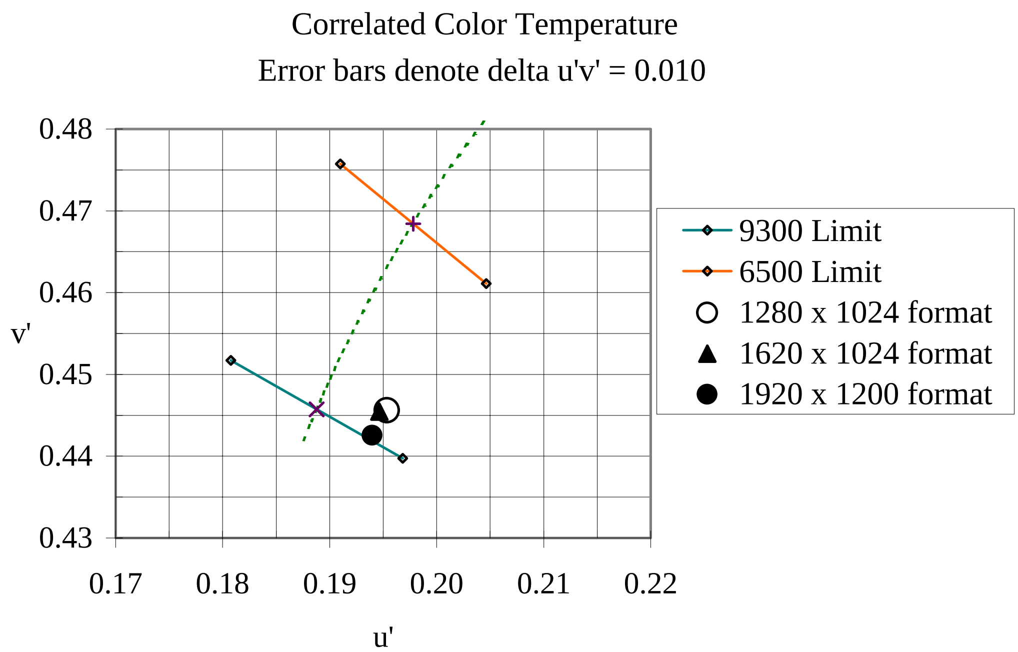


Figure II.5-1 *CCTs of measured whitepoints are within the boundaries required by IEC.*

Table II.5-1 Δu'v' Distances between measured whitepoints and CIE coordinate values from D_{65} to D_{93}.

	1280 x 1024	1620 x 1024	1920 x 1024
CIE x	0.291	0.290	0.287
CIE y	0.295	0.295	0.291
CIE u'	0.195	0.195	0.194
CIE v'	0.446	0.445	0.443
CCT	8613	8702	9132
delta u'v'	**0.007**	**0.006**	**0.006**

II.6. Bit Depth

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.6, p 6.

Positive increases in luminance were measured for each of the 256 input levels for 8 bits of gray scale. No black level clipping nor white level saturation were observed.

Objective: Measure the number of bits of data that can be displayed as a function of the DAC and display software.

Equipment: Photometer

Test targets: Targets are n four inch patches with command levels of all commandable levels; e.g., 256 for 8 bit display. Background is commanded to 0.5* ((0.7 *P)+0.3*n) where P = patch command level, n = number of command levels.

Procedure: Measure patch center for all patches with Lmin and Lmax as defined previously. Count number of monotonically increasing luminance levels. Use the NEMA/DICOM model to define discriminable luminance differences. For color displays, measure white values.

Data: Define bit depth by $\log_2$ (number of discrete luminance levels)

The number of bits of data that can be displayed as a function of the input signal voltage level were verified through measurements of the luminance of white test targets displayed using a Quantum Data 8701 test pattern generator and a Minolta CA-100 colorimeter. Targets are n four-inch patches with command levels of all commandable levels; e.g., 256 for 8 bit display. Background is commanded to 0.5* ((0.7 *P)+0.3*n) where P = patch command level, n = number of command levels. The NEMA/DICOM model was used to define discriminable luminance differences in JNDs.

Figure II.6-1 shows the System Tonal Transfer curve at center screen as a function of input counts. The data for each of the 256 levels are listed in Tables II.6-1 and II.6-2.

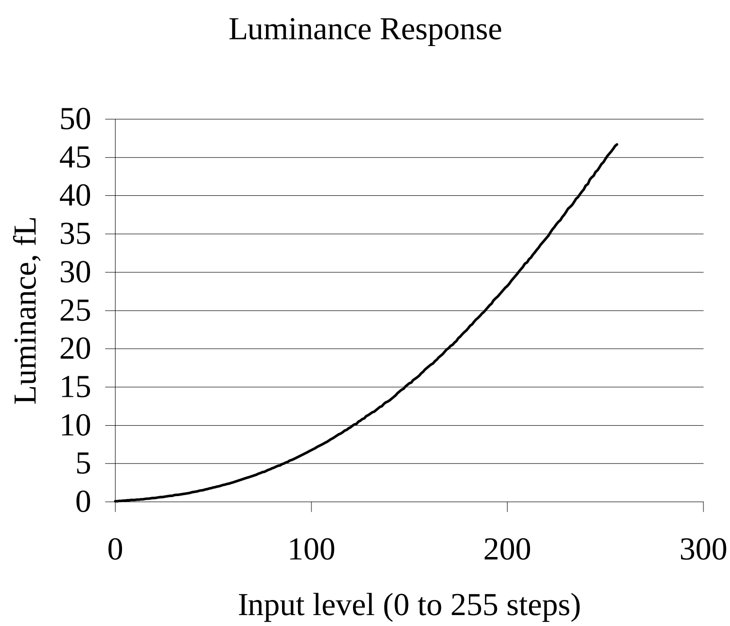


Figure II.6-1. System Tonal Transfer at center screen as a function of input counts.

Table II.6-1. System Tonal Transfer at center screen as a function of input counts. Target levels 000 to 127.

Back Ground	Target	L, fL	Diff, fL	Back Ground	Target	L, fL	Diff, fL
38	0	0.09	-----	61	64	2.87	0.08
39	1	0.1	0.01	61	65	2.95	0.08
39	2	0.13	0.03	62	66	3.05	0.1
39	3	0.14	0.01	62	67	3.14	0.09
40	4	0.15	0.01	62	68	3.2	0.06
40	5	0.18	0.03	63	69	3.29	0.09
41	6	0.19	0.01	63	70	3.39	0.1
41	7	0.21	0.02	63	71	3.48	0.09
41	8	0.23	0.02	64	72	3.57	0.09
42	9	0.25	0.02	64	73	3.68	0.11
42	10	0.27	0.02	64	74	3.78	0.1
42	11	0.29	0.02	65	75	3.87	0.09
43	12	0.31	0.02	65	76	3.94	0.07
43	13	0.33	0.02	65	77	4.04	0.1
43	14	0.35	0.02	66	78	4.16	0.12
44	15	0.38	0.03	66	79	4.26	0.1
44	16	0.41	0.03	66	80	4.38	0.12
44	17	0.43	0.02	67	81	4.48	0.1
45	18	0.46	0.03	67	82	4.58	0.1
45	19	0.49	0.03	67	83	4.71	0.13
45	20	0.51	0.02	68	84	4.78	0.07
46	21	0.55	0.04	68	85	4.91	0.13
46	22	0.58	0.03	69	86	5	0.09
46	23	0.61	0.03	69	87	5.14	0.14
47	24	0.64	0.03	69	88	5.22	0.08
47	25	0.68	0.04	70	89	5.37	0.15
48	26	0.71	0.03	70	90	5.46	0.09
48	27	0.74	0.03	70	91	5.58	0.12
48	28	0.78	0.04	71	92	5.71	0.13
49	29	0.81	0.03	71	93	5.84	0.13
49	30	0.86	0.05	71	94	5.97	0.13
49	31	0.9	0.04	72	95	6.09	0.12
50	32	0.93	0.03	72	96	6.23	0.14
50	33	0.97	0.04	72	97	6.34	0.11
50	34	1.02	0.05	73	98	6.48	0.14
51	35	1.06	0.04	73	99	6.63	0.15
51	36	1.1	0.04	73	100	6.76	0.13
51	37	1.14	0.04	74	101	6.89	0.13
52	38	1.19	0.05	74	102	7.03	0.14
52	39	1.24	0.05	74	103	7.17	0.14
52	40	1.29	0.05	75	104	7.3	0.13
53	41	1.33	0.04	75	105	7.44	0.14
53	42	1.39	0.06	76	106	7.58	0.14
53	43	1.45	0.06	76	107	7.73	0.15
54	44	1.5	0.05	76	108	7.87	0.14
54	45	1.55	0.05	77	109	8.03	0.16
55	46	1.61	0.06	77	110	8.17	0.14
55	47	1.67	0.06	77	111	8.31	0.14
55	48	1.74	0.07	78	112	8.48	0.17
56	49	1.79	0.05	78	113	8.65	0.17
56	50	1.87	0.08	78	114	8.8	0.15
56	51	1.92	0.05	79	115	8.95	0.15
57	52	1.99	0.07	79	116	9.11	0.16
57	53	2.06	0.07	79	117	9.31	0.2
57	54	2.12	0.06	80	118	9.4	0.09
58	55	2.2	0.08	80	119	9.59	0.19
58	56	2.25	0.05	80	120	9.75	0.16
58	57	2.33	0.08	81	121	9.95	0.2
59	58	2.4	0.07	81	122	10.1	0.15
59	59	2.48	0.08	81	123	10.2	0.1
59	60	2.56	0.08	82	124	10.5	0.3
60	61	2.63	0.07	82	125	10.6	0.1
60	62	2.72	0.09	83	126	10.8	0.2
60	63	2.79	0.07	83	127	10.9	0.1

Table II.6-2. System Tonal Transfer at center screen as a function of input counts
Target levels 128 to 255.

Back ground	Target	L, fL	Diff, fL
83	128	11.2	0.3
84	129	11.3	0.1
84	130	11.5	0.2
84	131	11.7	0.2
85	132	11.8	0.1
85	133	12	0.2
85	134	12.2	0.2
86	135	12.4	0.2
86	136	12.5	0.1
86	137	12.8	0.3
87	138	13	0.2
87	139	13.1	0.1
87	140	13.3	0.2
88	141	13.5	0.2
88	142	13.7	0.2
88	143	13.9	0.2
89	144	14.2	0.3
89	145	14.4	0.2
90	146	14.6	0.2
90	147	14.8	0.2
90	148	15.1	0.3
91	149	15.3	0.2
91	150	15.5	0.2
91	151	15.6	0.1
92	152	15.9	0.3
92	153	16.1	0.2
92	154	16.3	0.2
93	155	16.5	0.2
93	156	16.8	0.3
93	157	17	0.2
94	158	17.3	0.3
94	159	17.5	0.2
94	160	17.7	0.2
95	161	17.9	0.2
95	162	18.1	0.2
95	163	18.4	0.3
96	164	18.6	0.2
96	165	18.9	0.3
97	166	19.1	0.2
97	167	19.3	0.2
97	168	19.6	0.3
98	169	19.9	0.3
98	170	20.1	0.2
98	171	20.4	0.3
99	172	20.5	0.1
99	173	20.8	0.3
99	174	21	0.2
100	175	21.4	0.4
100	176	21.6	0.2
100	177	21.9	0.3
101	178	22.2	0.3
101	179	22.4	0.2
101	180	22.7	0.3
102	181	23	0.3
102	182	23.2	0.2
102	183	23.5	0.3
103	184	23.8	0.3
103	185	24	0.2
104	186	24.3	0.3
104	187	24.6	0.3
104	188	24.8	0.2
105	189	25.1	0.3
105	190	25.4	0.3
105	191	25.7	0.3

Back ground	Target	L, fL	Diff, fL
106	192	25.9	0.2
106	193	26.3	0.4
106	194	26.6	0.3
107	195	26.8	0.2
107	196	27.1	0.3
107	197	27.4	0.3
108	198	27.7	0.3
108	199	28	0.3
108	200	28.2	0.2
109	201	28.5	0.3
109	202	28.9	0.4
109	203	29.2	0.3
110	204	29.5	0.3
110	205	29.8	0.3
111	206	30.1	0.3
111	207	30.4	0.3
111	208	30.7	0.3
112	209	31.1	0.4
112	210	31.3	0.2
112	211	31.7	0.4
113	212	31.9	0.2
113	213	32.3	0.4
113	214	32.6	0.3
114	215	32.9	0.3
114	216	33.2	0.3
114	217	33.6	0.4
115	218	33.9	0.3
115	219	34.2	0.3
115	220	34.5	0.3
116	221	34.8	0.3
116	222	35.2	0.4
116	223	35.6	0.4
117	224	35.9	0.3
117	225	36.3	0.4
118	226	36.6	0.3
118	227	36.8	0.2
118	228	37.2	0.4
119	229	37.5	0.3
119	230	37.9	0.4
119	231	38.3	0.4
120	232	38.5	0.2
120	233	38.8	0.3
120	234	39.2	0.4
121	235	39.6	0.4
121	236	39.8	0.2
121	237	40.2	0.4
122	238	40.5	0.3
122	239	40.8	0.3
122	240	41.3	0.5
123	241	41.5	0.2
123	242	42.1	0.6
123	243	42.4	0.3
124	244	42.6	0.2
124	245	43.1	0.5
125	246	43.3	0.2
125	247	43.7	0.4
125	248	44.1	0.4
126	249	44.4	0.3
126	250	44.8	0.4
126	251	45.2	0.4
127	252	45.5	0.3
127	253	45.8	0.3
127	254	46.1	0.3
128	255	46.5	0.4

II.8. Luminance Step Response

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.8, p 7.

No video artifacts were observed.

Objective: Determine the presence of artifacts caused by undershoot or overshoot.

Equipment: Test targets, SMPTE Test Pattern RP-133-1991, 2-D CCD array

Procedure: Display a center box 15% of screen size at input count levels corresponding to 25%, 50%, 75%, and 100% of Lmax with a surround of count level 0. Repeat using SMPTE Test pattern

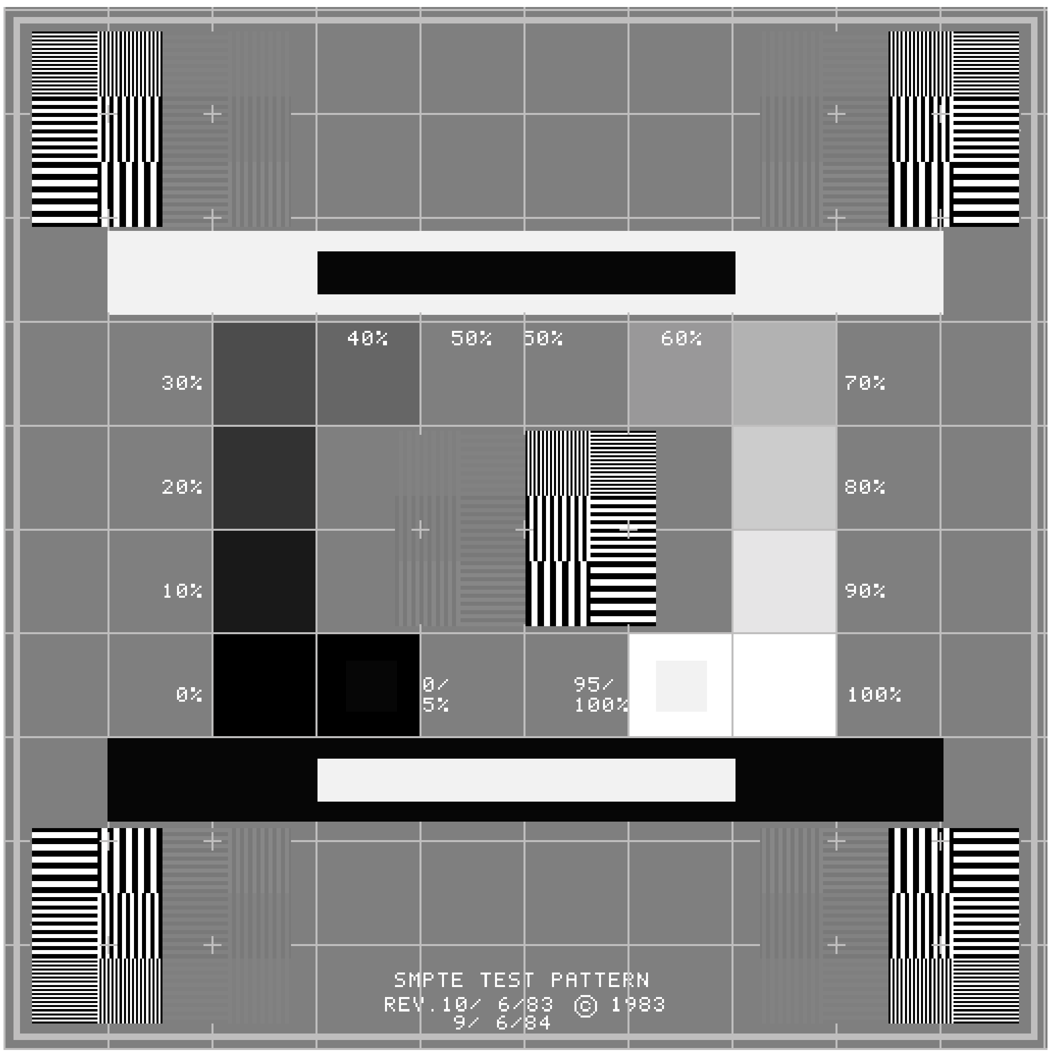


Figure II.8-1. SMPTE Test Pattern .

Data: Define pass by absence of noticeable ringing, undershoot, overshoot, or streaking.

The test pattern shown in Figure II.8-1 was used in the visual evaluation of the monitor. This test pattern is defined in SMPTE Recommended Practice RP-133-1986 published by the Society of Motion Picture and Television Engineers (SMPTE) for medical imaging applications. Referring to the large white-in-black and black-in-white horizontal bars contained in the test pattern, RP133-1986, paragraph 2.7 states " These areas of maximum contrast facilitate detection of mid-band streaking (poor low-frequency response), video amplifier ringing or overshoot, deflection interference, and halo." None of these artifacts was observed in the SUN 365-1352-01 monitor, signifying good electrical performance of the video circuits.

II.9. Addressability

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 6.1, page 67.

This monitor properly displayed all addressed pixels for the following tested formats (HxV): ***1280 x 1024x 72 Hz, 1620 x 1024x 72 Hz, 1920 x 1200x 60Hz, 1024 x 1024 x 120 Hz.***

Objective: Define the number of addressable pixels in the horizontal and vertical dimension; confirm that stated number of pixels is displayed.

Equipment: Programmable video signal generator.
Test pattern with pixels lit on first and last addressable rows and columns and on two diagonal lines beginning at upper left and lower right; H & V grill patterns 1-on/1-off.

Procedure: The number of addressed pixels were programmed into the Quantum Data 8701 test pattern generator for 72 Hz minimum for monoscopic mode and 120 Hz minimum for stereoscopic mode, where possible. All perimeter lines were confirmed to be visible, with no irregular jaggies on diagonals and, for monochrome monitors, no strongly visible moiré on grilles.

Data: If tests passed, number of pixels in horizontal and vertical dimension. If test fails, addressability unknown.

Table II.9-1 Addressabilities Tested

Monoscopic Modes			**Stereo Mode**
1280 x 1024	**1620 x 1024**	**1920 x 1200**	**1024 x 1024**

II.10. Pixel Aspect Ratio

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.10, p 8.

Pixel aspect ratio is within 0.7%.

Objective: Characterize aspect ratio of pixels.

Equipment: Test target, measuring tape with at least 1/16th inch increments

Procedure: Display box of 400 x 400 pixels at input count corresponding to 50% Lmax and background of 0. Measure horizontal and vertical dimension.

Alternatively, divide number of addressable pixels by the total image size to obtain nominal pixel spacings in horizontal and vertical directions.

Data: Define pass if H= V± 6% for pixel density <100 ppi and ± 10% for pixel density > 100 ppi.

	Monoscopic Modes		
Addressability (H x V)	**1280 x 1024**	**1620 x 1024**	**1920 x 1200**
H x V Image Size (inches)	15.078 H x 11.978 V	18.874H x 11.933 V	18.944 H x 11.917 V
H x V Pixel Spacing (mils)	11.78 x 11.70 mils	11.65 x 11.65	9.87 x 9.93
H x V Pixel Aspect Ratio	**H = V + 0.7%**	**H = V+ 0.0%**	**H = V - 0.6%**

II.11. Screen Size (Viewable Active Image)

Reference: VESA Flat Panel Display Measurements Standard, Version 1.0, May 15, 1998, Section 501-1.

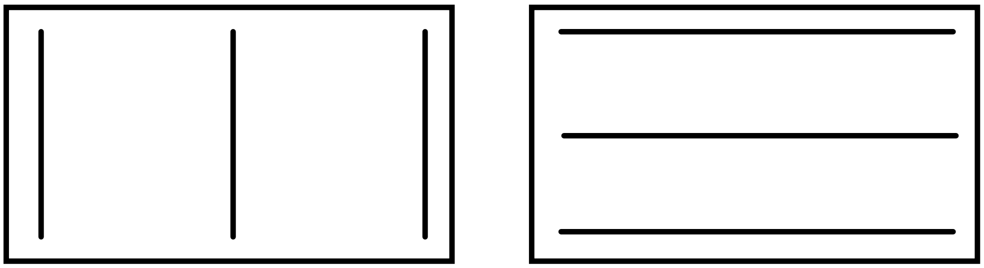
Image sizes ranged from 19.3 inches to 22.4 inches in diagonal.

Objective: Measure beam position on the CRT display to quantify width and height of active image size visible by the user (excludes any overscanned portion of an image).

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Calibrated X-Y translation stage

Test Pattern: Use the three-line grille patterns in Figure II.11-1 for vertical and horizontal lines each 1-pixel wide. Lines in test pattern are displayed at 100% L_{max} must be

positioned along the top, bottom, and side edges of the addressable screen, as well as along both the vertical and horizontal centerlines (major and minor axes).



1-pixel-wide lines displayed at 100% L_{max}

Figure II.11-1 Three-line grille test patterns.

Procedure: Use diode optic module to locate center of line profiles in conjunction with calibrated X-Y translation to measure screen x,y coordinates of lines at the ends of the major and minor axes.

Data: Compute the image width defined as the average length of the horizontal lines along the top, bottom and major axis of the screen. Similarly, compute the image height defined as the average length of the vertical lines along the left side, right side, and minor axis of the screen. Compute the diagonal screen size as the square-root of the sum of the squares of the width and height.

Table II.11-1. Image Size

	Monoscopic Modes		
Addressability (H x V)	**1280 x 1024**	**1620 x 1024**	**1920 x 1200**
H x V Image Size (inches) Diagonal Image Size (inches)	15.078 x 11.978 **19.256**	18.874 x 11.933 **22.329**	18.944 x 11.917 **22.381**

II.12. Contrast Modulation

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 5.2, page 57.

Contrast modulation (Cm) for 1-on/1-off grille patterns displayed at 50% Lmax exceeded Cm = 51% in Zone A, and exceeded Cm = 35% in Zone B.

Objective: Quantify contrast modulation as a function of screen position.

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Photometer with linearized response

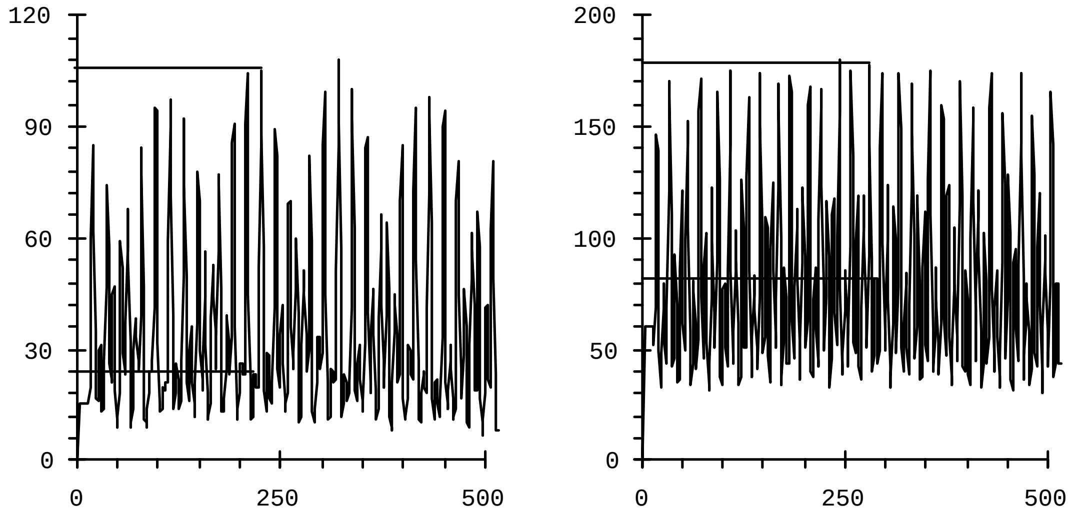
Procedure: The maximum video modulation frequency for each format (1280 x 1024, 1620 x 1024, 1920 x 1200) was examined using horizontal and vertical grille test patterns consisting of alternating lines with 1 pixel on, 1 pixel off. Contrast modulation was measured in both horizontal and vertical directions at screen center and at eight peripheral screen positions. The measurements should be along the horizontal and vertical axes and along the diagonal from these axes. Use edge measurements no more than 10% of screen size in from border of active screen. The input signal level was set so that 1-line-on/1-line-off horizontal grille patterns produced a screen area-luminance of 25% of maximum level, Lmax..

Zone A is defined as a 24 degree subtense circle from a viewing distance of 18 inches (7.6 inch circle). Zone B is the remainder of the display. Use edge measurements no more than 10% of screen size in from border of active screen area to define Cm for Zone B (remaining area outside center circle). Determine Cm at eight points on circumference of circle by interpolating between center and display edge measurements to define Cm for Zone A. If measurements exceed the threshold, do not make any more measurements. If one or more measurements fail the threshold, make eight additional measurements at the edge (but wholly within) the defined circle.

Data: Values of vertical and horizontal Cm for Zone A and Zone B are given in Table II.12-1. The contrast modulation, Cm, is reported (the defining equation is given below) for the 1-on/1-off grille patterns. The modulation is equal to or greater than 51% in Zone A, and is equal to or greater than 35% in Zone B.

$$C_m = \frac{L_{peak} - L_{valley}}{L_{peak} + L_{valley}}$$

The sample contrast modulations shown in Figure II.12-1 for two different color CRTs are not fully realized because of the presence of moiré caused by aliasing between the image and the shadowmask. Because contrast modulation values are calculated for the maximum peak and minimum valley luminance levels as indicated in the sample data shown, they do not include the degrading effects of aliasing.



Monitor A
0.28mm dot pitch

Monitor B
0.26mm dot pitch

Figure II.12-1. *Contrast modulation for sample luminance profiles (1 pixel at input level corresponding to 50% Lmax, 1 pixel at level 0 = Lmin) for monitors exhibiting moiré due to aliasing.*

Table II.12-1. Contrast Modulation
Corrected for lens flare and Zone Interpolation

1280 x 1024

	Left				Minor				Right	
	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille
Top	36%	61%			62%	77%			50%	63%
			60%	71%	67%	78%	65%	72%		
Major	55%	68%	65%	73%	75%	78%	69%	74%	63%	71%
			67%	71%	72%	73%	68%	74%		
Bottom	54%	61%			70%	71%			58%	67%

1620 x 1024

	Left				Minor				Right	
	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille
Top	72%	60%			65%	58%			80%	58%
			75%	70%	69%	64%	78%	69%		
Major	87%	67%	80%	72%	76%	75%	80%	70%	87%	62%
			79%	68%	68%	69%	77%	70%		
Bottom	84%	53%			64%	66%			79%	61%

1920 x 1200

	Left				Minor				Right	
	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille
Top	67%	42%			48%	48%			85%	41%
			64%	54%	53%	52%	70%	53%		
Major	82%	45%	70%	54%	62%	60%	70%	52%	83%	40%
			68%	53%	54%	53%	66%	51%		
Bottom	79%	41%			49%	49%			73%	35%

II.13. Pixel Density

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.13, p 9.

Pixel density was 85 ppi for 1024-line addressable formats, and 101 ppi for 1200-line formats.

Objective: Characterize density of image pixels

Equipment: Measuring tape with at least 1/16 inch increments

Procedure: Measure H&V dimension of active image window and divide by vertical and horizontal addressability

Data: Define horizontal and vertical pixel density in terms of pixels per inch

Table II.13-1. Pixel-Density

	Monoscopic Modes		
H x V Addressability, Pixels	**1280 x 1024**	**1620 x 1024**	**1920 x 1200**
H x V Image Size, Inches	15.078 x 11.978	18.874 x 11.933	18.944 x 11.917
H x V Pixel Density, ppi	**84.9 x 85.5**	**85.8 x 85.8**	**101.4 x 100.7**

II.14. Moire

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.14, p 9.

Phosphor-to-pixel spacing ratios are less than 1.0 except for the 1920 x 1200 format (ratio = 1.12).. Compensation circuitry effectively reduces the visibility of moire patterns when displaying 1-on/1-off vertical grille patterns.

Objective: Determine lack of moiré.

Equipment Loupe with scale graduated in 0.001 inch or equivalent

Procedure Measure phosphor pitch in vertical and horizontal dimension at screen center. For aperture grille screens, vertical pitch will be 0. Define pixel size by 1/pixel density.

Data: Define value of phosphor: pixel spacing. Value <1 passes, but <0.6 preferred.

Table II.14-1. Phosphor-to-Pixel-Spacing Ratios

	Monoscopic Modes		
Addressability	**1280 x 1024**	**1620 x 1024**	**1920 x 1200**
Pixel Spacing	11.78 mils	11.65 mils	9.87 mils
Phosphor Pitch	0.28	0.28	0.28
Phosphor-to-Pixel-Spacing	**0.94**	**0.95**	**1.12**

Discussion: Moiré occurs when the phosphor pitch is too large in comparison to the pixel size. Studies have shown that a phosphor pitch of about 0.6 pixels or less is required for adequate visibility of image information without interference from the phosphor structure.

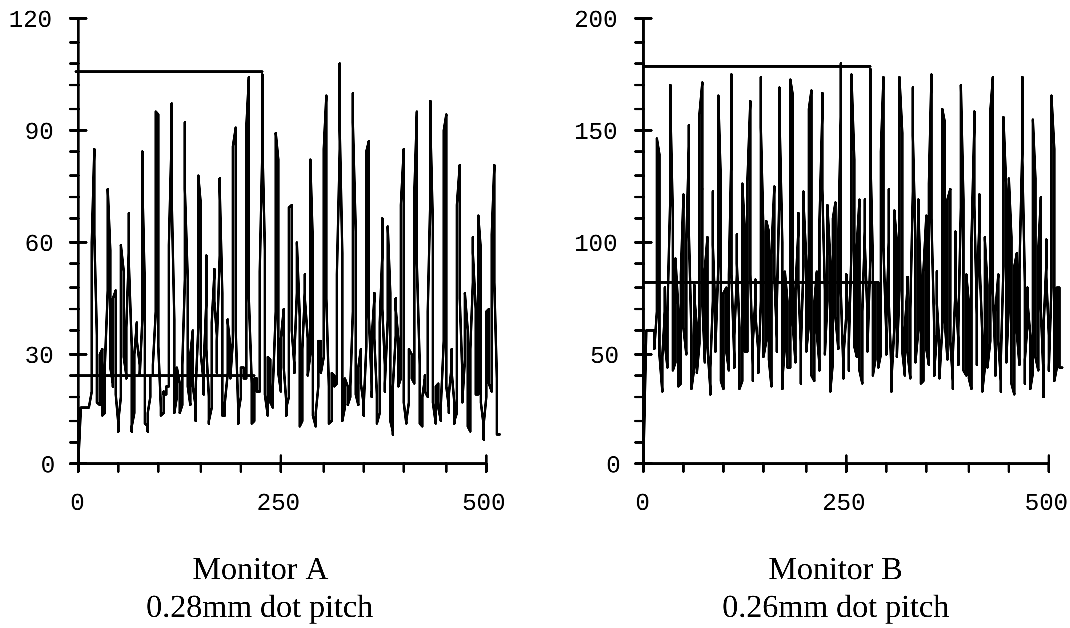


Figure II.12-1. *Contrast modulation for sample luminance profiles (1pixel at level 50, 1 pixel at level 0) for monitors exhibiting moiré due to aliasing.*

In Figure II.12-1, Monitor A phosphor pitch is 0.90 pixels as compared with 0.84 pixels in Monitor B. Moiré is more visible in Monitor A, appearing as long stripes where contrast modulation has been degraded. In Monitor B, moiré is less visible, appearing as "fish-scales" where contrast modulation has been reduced. Even though the Monitor A exhibits a greater loss of contrast modulation from the presence of moiré on 1-on/1-off vertical grille patterns, there is little or no visual impact when aerial photographic images are displayed. NIDL experts in human vision and psychophysics were unable to discern presence of moire on either monitor when grayscale imagery was displayed.

II.15. Straightness

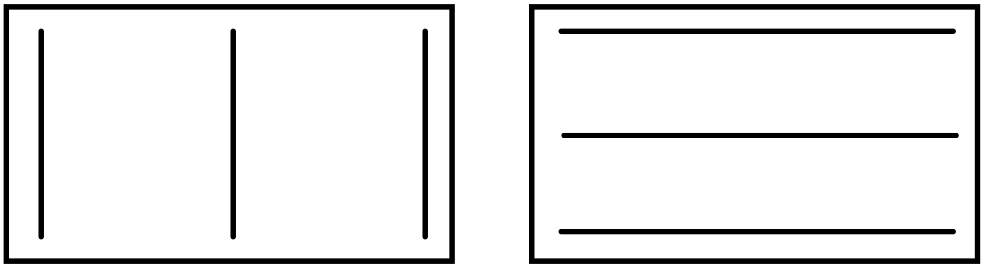
Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 6.1 Waviness, page 67.

Waviness, a measure of straightness, did not exceed 0.36%.

Objective: Measure beam position on the CRT display to quantify effects of waviness which causes nonlinearities within small areas of the display distorting nominally straight features in images, characters, and symbols.

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Calibrated X-Y translation stage

Test Pattern: Use the three-line grille patterns in Figure II.15-1 for vertical and horizontal lines each 1-pixel wide. Lines in test pattern are displayed at 100% L_{max} must be positioned along the top, bottom, and side edges of the addressable screen, as well as along both the vertical and horizontal centerlines (major and minor axes).



1-pixel-wide lines displayed at 100% L_{max}

Figure II.15-1 Three-line grille test patterns.

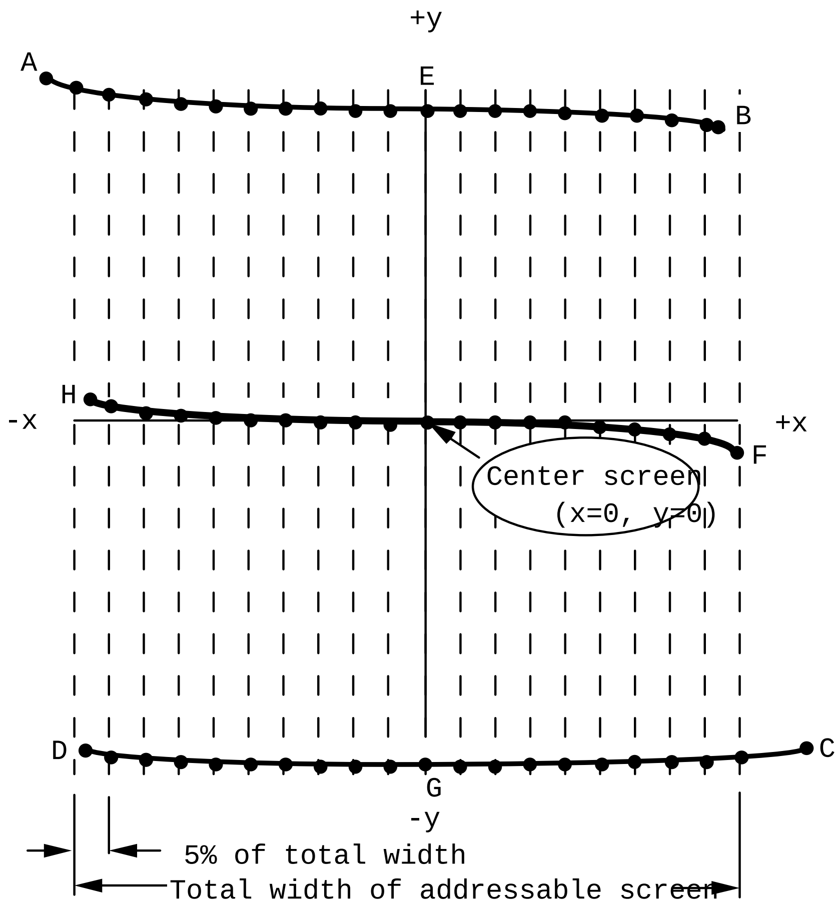


Figure II.15-2 Measurement locations for waviness along horizontal lines. Points A, B, C, D are extreme corner points of addressable screen. Points E, F, G, H are the endpoints of the axes.

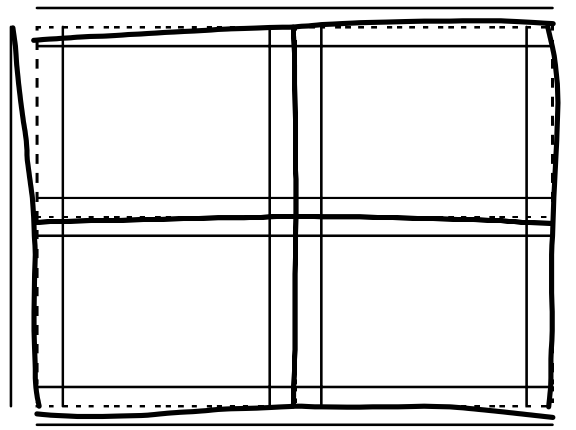
Procedure: Use diode optic module to locate center of line profiles in conjunction with calibrated X-Y translation to measure screen x,y coordinates along the length of a nominally straight line. Measure x,y coordinates at 5% addressable screen intervals along the line. Position vertical lines in video to land at each of three (3) horizontal screen locations for determining waviness in the horizontal direction. Similarly, position horizontal lines in video to land at each of three (3) vertical screen locations for determining waviness in the vertical direction.

Data: Tabulate x,y positions at 5% addressable screen increments along nominally straight lines at top and bottom, major and minor axes, and left and right sides of the screen as shown in Table II.15-I. Figure II.15-3 shows the results in graphical form.

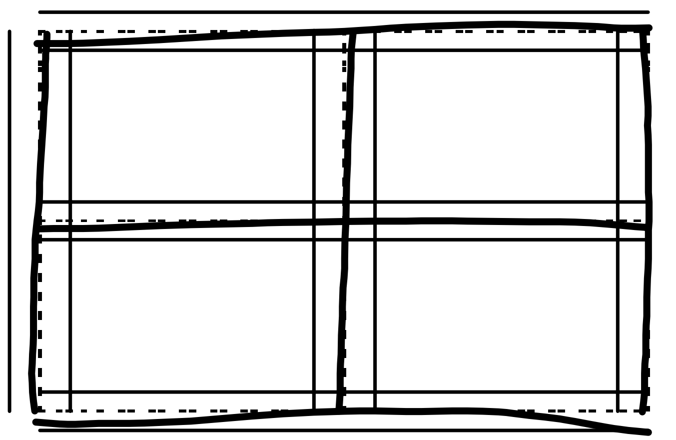
Table II.15-1. Straightness

Tabulated x,y positions at 5% addressable screen increments along nominally straight lines.

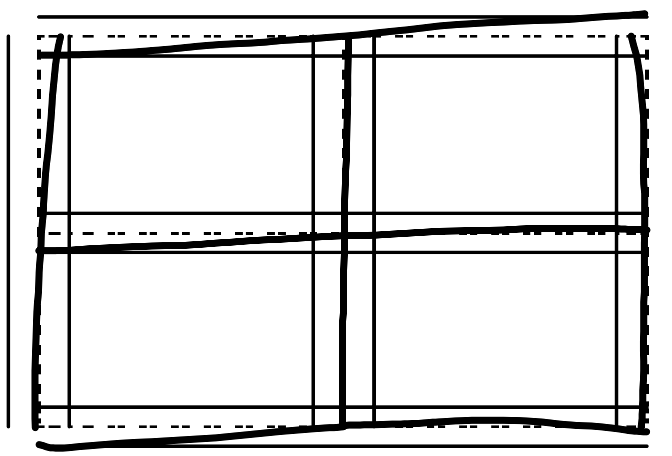
Top		Bottom		Major		Minor		Left Side		Right Side	
x	y	x	y	x	y	x	y	x	y	x	y
-7639	5984	-7544	-6001	-7542	-14	-9	6000	-7609	5973	7500	6000
-6750	5991	-6750	-6007	-6750	-12	-6	5400	-7602	5400	7513	5400
-6000	5996	-6000	-6009	-6000	-10	-4	4800	-7598	4800	7523	4800
-5250	5999	-5250	-6008	-5250	-8	-4	4200	-7592	4200	7528	4200
-4500	6004	-4500	-6006	-4500	-6	-3	3600	-7586	3600	7530	3600
-3750	6009	-3750	-5999	-3750	-4	-2	3000	-7578	3000	7528	3000
-3000	6013	-3000	-5994	-3000	-2	-1	2400	-7570	2400	7526	2400
-2250	6018	-2250	-5987	-2250	0	-2	1800	-7567	1800	7524	1800
-1500	6021	-1500	-5984	-1500	0	0	1200	-7560	1200	7521	1200
-750	6024	-750	-5981	-750	3	0	600	-7552	600	7518	600
0	6026	0	-5976	0	4	0	0	-7549	0	7516	0
750	6033	750	-5979	750	3	-1	-600	-7547	-600	7514	-600
1500	6037	1500	-5980	1500	3	-2	-1200	-7544	-1200	7512	-1200
2250	6040	2250	-5979	2250	2	-3	-1800	-7546	-1800	7512	-1800
3000	6043	3000	-5978	3000	0	-3	-2400	-7547	-2400	7512	-2400
3750	6045	3750	-5976	3750	-2	-3	-3000	-7548	-3000	7513	-3000
4500	6045	4500	-5979	4500	-4	-3	-3600	-7548	-3600	7513	-3600
5250	6046	5250	-5986	5250	-6	-3	-4200	-7546	-4200	7511	-4200
6000	6046	6000	-5994	6000	-10	-5	-4800	-7544	-4800	7510	-4800
6750	6041	6750	-6003	6750	-15	-7	-5400	-7542	-5400	7509	-5400
7512	6036	7501	-6012	7495	-17	-9	-5976	-7533	-5984	7503	-6000



1280 x 1024



1620 x 1024



1920 x 1200

Figure II.15-3 Waviness of Sun Microsystems 365-365-1352-01 Color monitor in 1280 x 1024, 1620 x 1024, and 1920 x 1200 modes. Departures from straight lines are exaggerated on a 10X scale. Error bars are +/- 0.5% of total screen size.

II.16. Refresh Rate

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.16, p 9.

Vertical refresh rate for 1280 x 1024 and 1620 x 1024 formats was set to 72 Hz.
Vertical refresh rate for the 1920 x 1200 format was set to 60 Hz,but not limited by the monitor (76Hz maximum).
Vertical refresh rate for the 1024 x 1024 stereo format was 92 Hz, limited by the monitor.

Objective: Define vertical and horizontal refresh rates.

Equipment: Programmable video signal generator.

Procedure: The refresh rates were programmed into the Quantum Data 8701 test pattern generator for 72 Hz minimum for monoscopic mode and 120 Hz minimum for stereoscopic mode, where possible.

Data: Report refresh rates in Hz.

Table II.16-1 Refresh Rates as Tested

	Monoscopic Modes			**Stereo Mode**
Addressability	**1280 x 1024**	**1620 x 1024**	**1920 x 1200**	**1024 x 1024**
Vertical Scan	72 Hz	72 Hz	60 Hz	92 Hz
Horizontal Scan	75.7 kHz	75.7 kHz	76.3 kHz	97.5 kHz

II.17. Extinction Ratio

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.17, p10.

Stereo extinction ratio was averaged 12.9 to 1 (12.4 left, 13.4 right) at screen center. Luminance of white varied by up to 14.3% across the screen. Chromaticity variations of white were less than 0.007 delta u'v' units.

Objective: Measure stereo extinction ratio

Equipment: Two “stereo” pairs with full addressability. One pair has left center at command level of 255 (or Cmax) and right center at 0. The other pair has right center at command level of 255 (or Cmax) and left center at 0.

Stereoscopic-mode measurements were made using a commercially-available Nuvision 19-inch LCD shutter with passive polarized eyeglasses.

Procedure: Calibrate monitor to 0.1 fL Lmin and 35 fL Lmax (no ambient). Measure ratio of Lmax to Lmin on both left and right side images through the stereo system.

Data: Extinction ratio (left) = L (left,on, white/black)/left,off, black/white)

L(left,on, white/black) ~ trans(left,on)*trans(stereo)*L(max)*Duty(left)
+ trans(left,off)*trans (stereo)*L(min)*Duty (right)
Use left,off/right,on to perform this measurement

Extinction ratio (right) = L (right,on,white/black)/right,off, black/white)

L(right,on, white/black) ~
trans(right,on)*trans(stereo)*L(max)*Duty(right)
+ trans(right,off)*trans (stereo)*L(min)*Duty (left)
Use left,on/right,off to perform this measurement

Stereo extinction ratio is average of left and right ratios defined above.

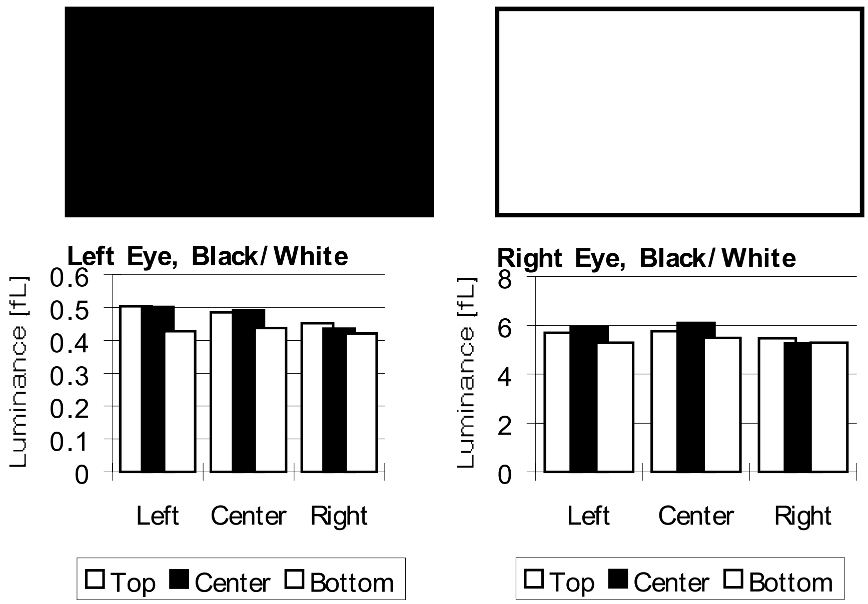


Fig.II.17-1. Spatial Uniformity of luminance in stereo mode when displaying black to the left eye while displaying white to the right eye.

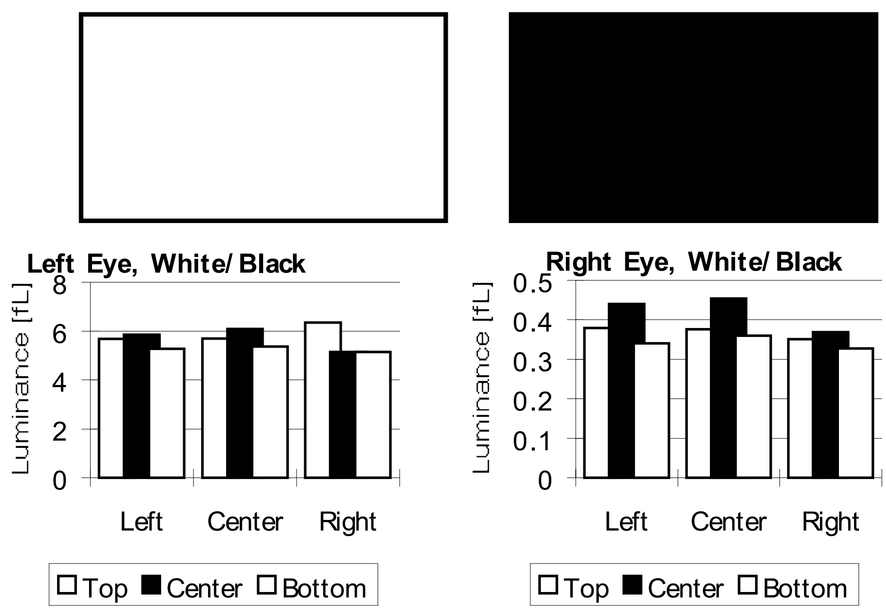


Fig.II.17-2. Spatial Uniformity of luminance in stereo mode when displaying white to the left eye while displaying black to the right eye.

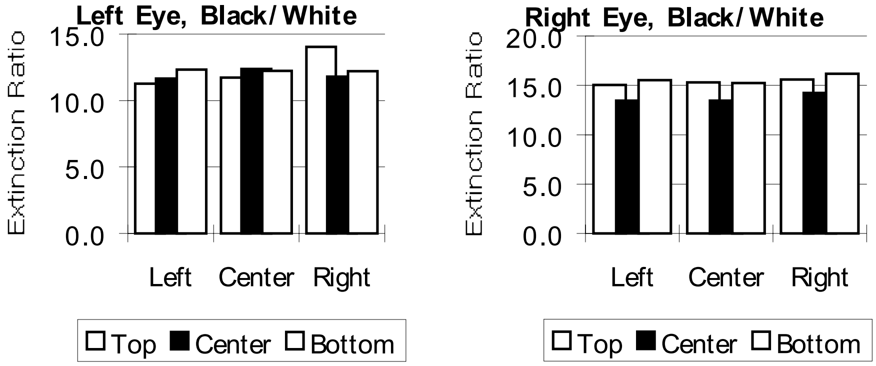


Fig.II.17-3. Spatial Uniformity of extinction ratio in stereo mode.

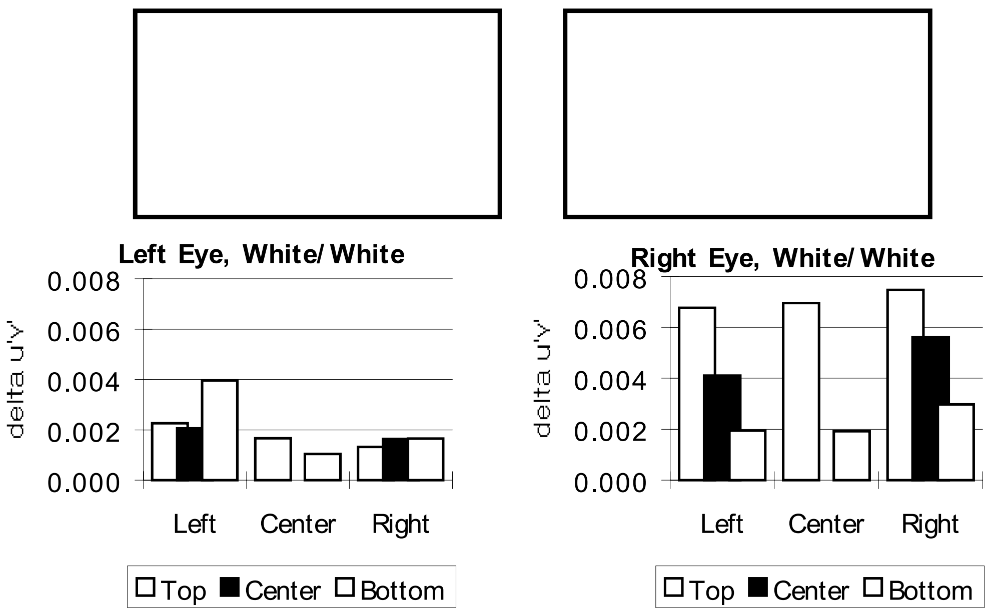


Fig.II.17-4 Spatial Uniformity of chromaticity of white in stereo mode.

II.18. Linearity

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 6.2, page 73.

The maximum nonlinearity of the scan was 0.87% of full screen.

Objective: Measure the relation between the actual position of a pixel on the screen and the commanded position to quantify effects of raster nonlinearity. Nonlinearity of scan degrades the preservation of scale in images across the display.

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Calibrated X-Y translation stage

Test Pattern: Use grille patterns of single-pixel horizontal lines and single-pixel vertical lines displayed at 100% L_{max}. Lines are equally spaced in addressable pixels. Spacing must be constant and equal to approximately 5% screen width and height to the nearest addressable pixel as shown in Figure II.18-1.

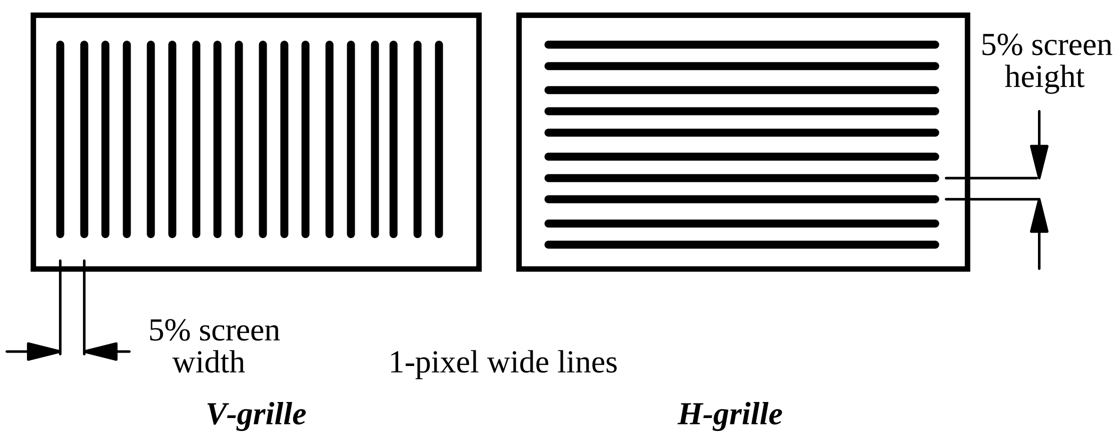


Figure II.18-1. *Grille patterns for measuring linearity*

Procedure: The linearity of the raster scan is determined by measuring the positions of lines on the screen. Vertical lines are measured for the horizontal scan, and horizontal lines for the vertical scan. Lines are commanded to 100% Lmax and are equally spaced in the time domain by pixel indexing on the video test pattern. Use optic module to locate center of line profiles in conjunction with x,y-translation stage to measure screen x,y coordinates of points where video pattern vertical lines intersect horizontal centerline of screen and where horizontal lines intersect vertical centerline of the CRT screen as shown in Figure II.18-2.

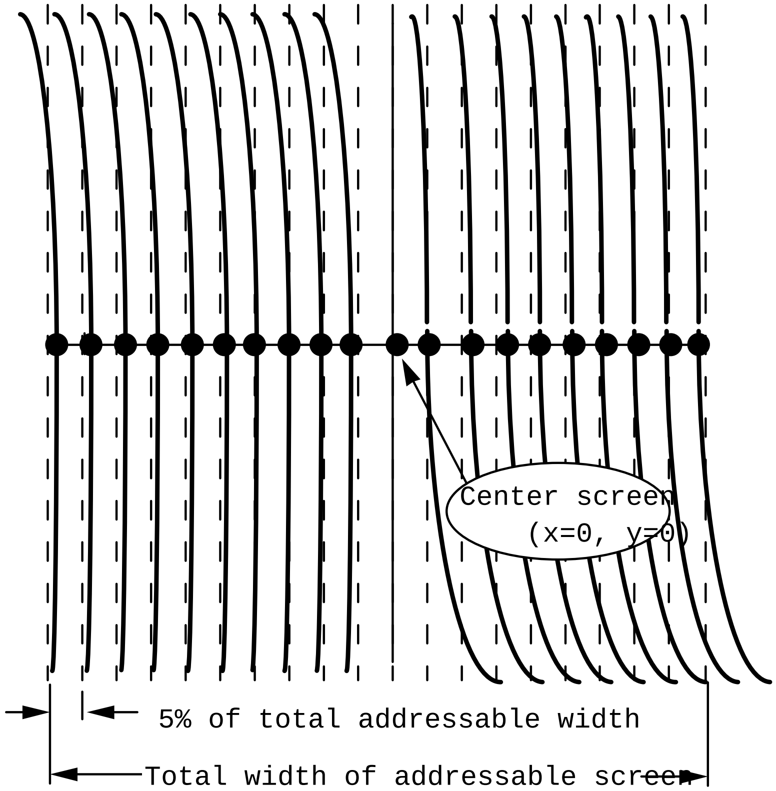


Figure II.18-2. *Measurement locations for horizontal linearity along the major axis of the display. Equal pixel spacings between vertical lines in the grille pattern are indicated by the dotted lines. The number of pixels per space is nominally equivalent to 5% of the addressable screen size.*

Data: Tabulate x,y positions of equally spaced lines (nominally 5% addressable screen apart) along major (horizontal centerline) and minor (vertical centerline) axes of the raster. If both scans were truly linear, the differences in the positions of adjacent lines would be a constant. The departures of these differences from constancy impacts the absolute position of each pixel on the screen and is, then, the nonlinearity. The degree of nonlinearity may be different between left and right and between top and bottom. The maximum horizontal and vertical nonlinearities (referred to full screen size) are listed in table II.18-1. The complete measured data are listed in table II.18-2 and shown graphically in Figure II.18-3.

Table II.18-1. Maximum Horizontal and Vertical Nonlinearities

Format	Left Side	Right Side	Top	Bottom
1280 x 1024	0.15%	0.25%	0.76%	0.28%
1620 x 1024	0.87%	0.45%	0.76%	0.30%
1920 x 1200	0.19%	0.15%	0.41%	0.59%

Table II.18-2. Horizontal and Vertical Nonlinearities Data

	Vertical Lines x-Position (mils)		Horizontal lines y-Position (mils)	
1280 x 1024				
	Left Side	Right Side	Top	Bottom
	-7423	7407	6011	-5954
	-6694	6679	5376	-5343
	-5959	5943	4760	-4742
	-5216	5202	4152	-4142
	-4469	4458	3553	-3549
	-3721	3717	2957	-2957
	-2978	2973	2364	-2365
	-2232	2230	1772	-1774
	-1489	1485	1184	-1184
	-744	745	592	-592
	0	0	0	0
1620 x 1024				
	Left Side	Right Side	Top	Bottom
	-9394	9307	5971	-5916
	-8457	8391	5341	-5310
	-7512	7451	4729	-4712
	-6552	6510	4125	-4117
	-5608	5569	3531	-3526
	-4657	4633	2939	-2938
	-3713	3701	2349	-2349
	-2778	2771	1763	-1763
	-1850	1847	1177	-1176
	-923	923	588	-588
	0	0	0	0
1920 x 1200				
	Left Side	Right Side	Top	Bottom
	-9284	9285	5868	-5846
	-8388	8386	5275	-5268
	-7470	7464	4690	-4690
	-6542	6530	4108	-4109
	-5605	5592	3525	-3528
	-4665	4654	2942	-2946
	-3727	3717	2357	-2361
	-2792	2787	1770	-1775
	-1859	1856	1181	-1185
	-930	929	591	-592
	0	0	0	0

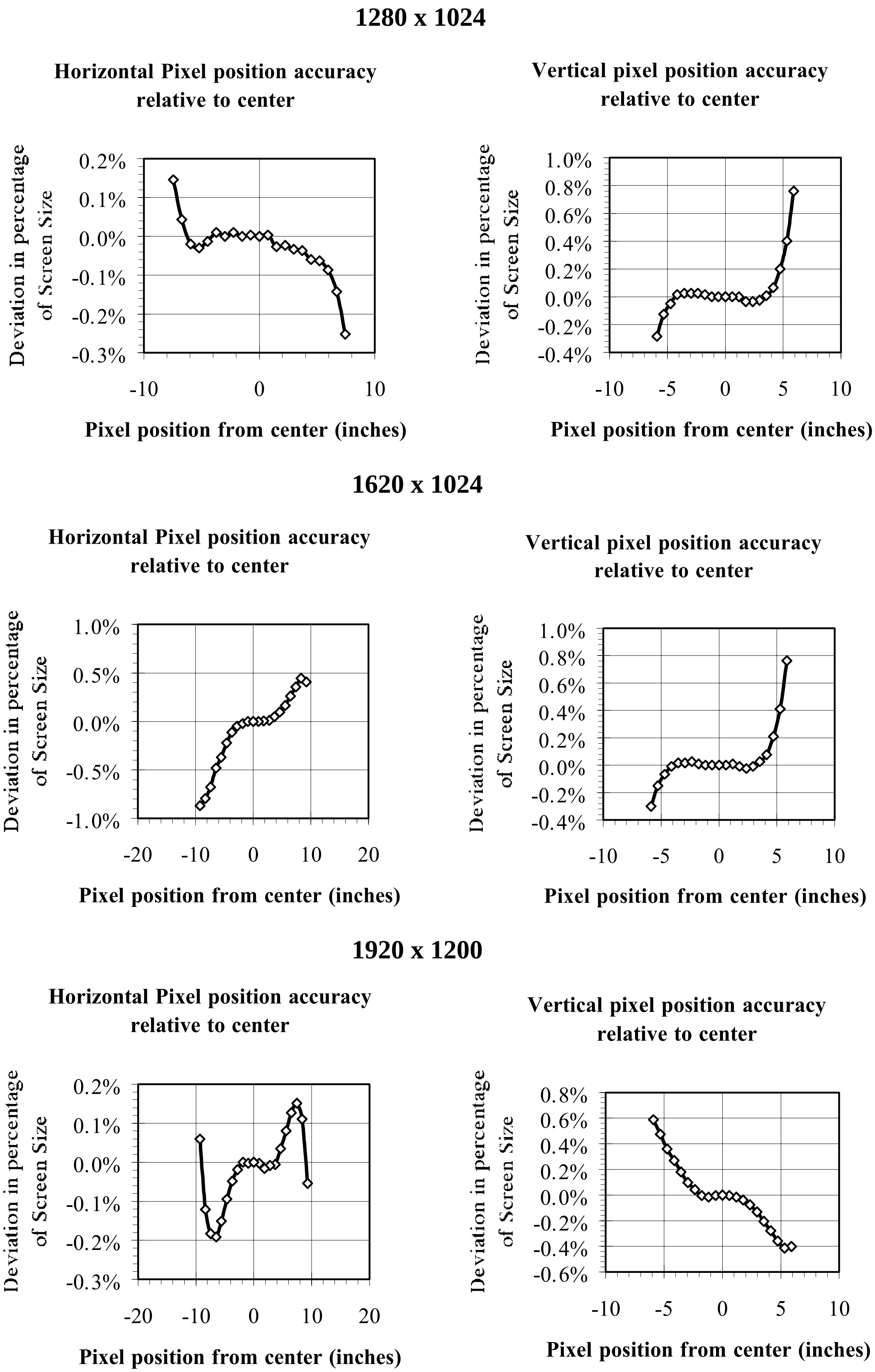


Fig. II.18-5 Horizontal and vertical linearity characteristics.

II.19. Jitter/Swim/Drift

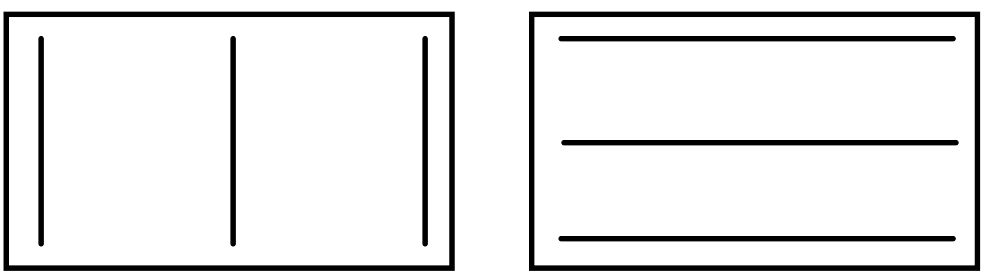
Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 6.4, p80.

Maximum jitter and swim/drift was 2.59 mils and 3.15 mils, respectively.

Objective: Measure amplitude and frequency of variations in beam spot position of the CRT display. Quantify the effects of perceptible time varying raster distortions: jitter, swim, and drift. The perceptibility of changes in the position of an image depend upon the amplitude and frequency of the motions which can be caused by imprecise control electronics or external magnetic fields.

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Calibrated X-Y translation stage

Test Pattern: Use the three-line grille patterns in Figure II.19-1 for vertical and horizontal lines each 1-pixel wide. Lines in test pattern must be positioned along the top, bottom, and side edges of the addressable screen, as well as along both the vertical and horizontal centerlines (major and minor axes).



V-grille for measuring horizontal motion H-grille for measuring vertical motion

1-pixel wide lines

Three-line grille test patterns.
Figure II.19-1

Procedure: With the monitor set up for intended scanning rates, measure vertical and horizontal line jitter (0.01 to 2 seconds), swim (2 to 60 seconds) and drift (over 60 seconds) over a 2.5 minute duration as displayed using grille video test patterns. Generate a histogram of raster variance with time. The measurement interval must be equal to a single field period.

Optionally, for multi-sync monitors measure jitter over the specified range of scanning rates. Some monitors running vertical scan rates other than AC line frequency may exhibit increased jitter.

Measure and report instrumentation motion by viewing Ronchi ruling or illuminated razor edge mounted to the top of the display. It may be necessary to mount both the optics and the monitor on a vibration damped surface to reduce vibrations.

Data: Tabulate motion as a function of time in x-direction at top-left corner screen location. Repeat for variance in y-direction. Tabulate maximum motions (in mils) with display input count level corresponding to L_{max} for jitter (0.01 to 2 seconds), swim (2 to 60 seconds) and drift (over 60 seconds) over a 2.5 minute duration. The data are presented in Table II.19-1. Both the monitor and the Microvision equipment sit on a vibration-damped aluminum-slab measurement bench. The motion of the test bench was a factor of 10 times smaller than the CRT raster motion.

Table II.19-1. Jitter/Swim/Drift

Time scales: Jitter 2 sec., Swim 10 sec., and Drift 60 sec.

1920 x 1200 x 60hz

			H-lines	V-lines	
10D corner	Max Motions				
		Jitter	1.78	2.85	
		Swim	1.86	3.31	
		Drift	1.91	3.41	
Black Tape	Max Motions				
		Jitter	0.278	0.259	
		Swim	0.278	0.259	
		Drift	0.307	0.262	
Less Tape Motion					maximums
		Jitter	1.50	2.59	2.59
		Swim	1.58	3.05	3.05
		Drift	1.60	3.15	3.15

1280 x 1024 x 72 Hz

generator			**Quantum Data FOX 8701**		**Quantum Data 903**	
			H-lines	V-lines	H-lines	V-lines
10D corner	Max Motions					
		Jitter	1.12	2.28		2.53
		Swim	1.33	2.56		2.7
		Drift	1.36	2.77		2.9
Center	Max Motions					
		Jitter	1.29	1.92		
		Swim	1.49	2.04		
		Drift	1.48	2.28		

II.20 Warmup Period

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.20, p. 10.

A 23 minute warmup was necessary for luminance stability of Lmin = 0.11 fL +/- 10%.

Objective: Define warm-up period

Equipment: Photometer, test target (full screen 0 count)

Procedure: Turn monitor off for three-hour period. Turn monitor on and measure center of screen luminance (Lmin as defined in Dynamic range measurement) at 1-minute intervals for first five minutes and five minute intervals thereafter. Discontinue when three successive measurements are ± 10% of Lmin.

Data: Pass if Lmin within ± 50% in 30 minutes and ±10% in 60 minutes.

The luminance of the screen (commanded to the minimum input level, 0 for Lmin) was monitored for 120 minutes after a cold start. Measurements were taken every minute. Figure II.20-1 shows the data for 1280 x 1024 format in graphical form. The luminance remains very stable after 23 minutes.

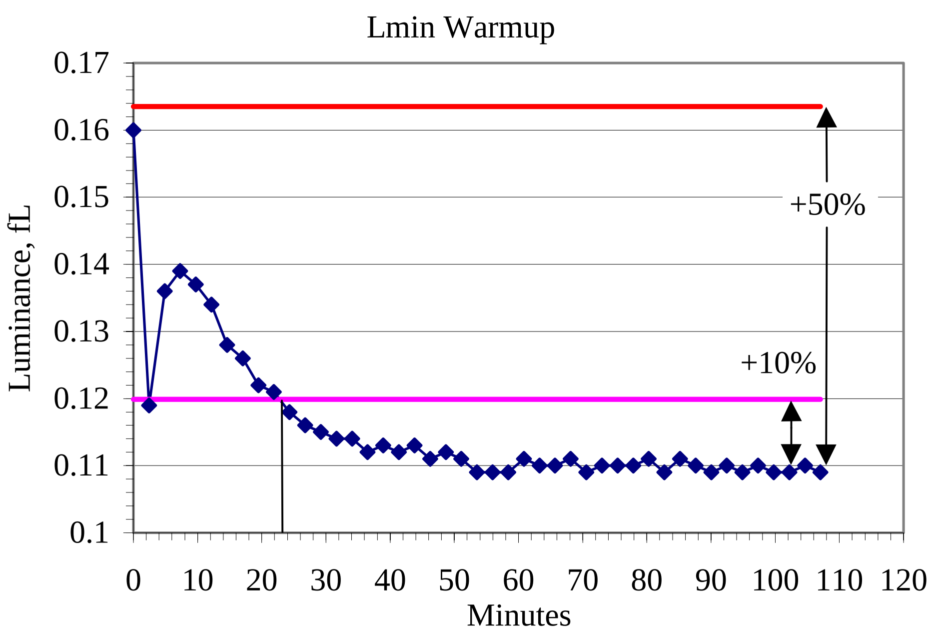


Figure II.20.1. Luminance (fL) as a function of time (in minutes) from a cold start with an input count of 0. (Note suppressed zero on luminance scale).